

**APPLICATION NOTE**

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**CONTINUOUS DYNAMIC ANALYSIS AND QUASI-STATIC MEASUREMENT OF SPIDER SILKS**

innovation center

APPLICATION

AUTHOR

**INTRODUCTION**

Nano-scale characterization of biological materials continues to be a challenge in the fields of mechanics and material testing. One interesting example is the mechanical properties of spider silks. The potential applications for these extraordinary materials range from medical to military. At **MTS** Nano Instruments, characterization of a variety of spider silks is being performed with great accuracy and repeatability using the **NANO Bionix®** universal testing system.

**PROBLEM**

Research into the mechanical properties of spider silks remains a newly-developing concept. **MTS** NANO is working with other researchers to remain on the forefront of this research. Spider silks have a truly astounding strength-to-weight ratio that makes them of interest to a number of communities. Problems associated with this research include the small and difficult to measure diameter of these silks together with difficulties in harvesting and gripping the samples. **MTS** NANO is using a new product, **NANO Bionix**, to help solve these problems.

**AN OVERVIEW OF NANO BIONIX**

**NANO Bionix** is a tensile testing machine that is capable of measuring force and extension on the nano-scale with impressive noise control. The extension axis, driven by a screw drive-train, operates with better than 35 nm resolution using a rotary encoder. The **NMAT** (Nanomechanical actuating transducer) measures the force on the specimen with a 50 nN resolution. It also enables the collection of meaningful dynamic data by superimposing an oscillatory force onto the quasi-static loading of the specimen. The following summary will help to demonstrate the quantitative abilities of the **NANO Bionix** to accurately measure material mechanical properties of interest.

figure 1: (top left image)

SEM Image of 500 nm *Uloborus diversus* spider silk

figure 2: (middle left image)

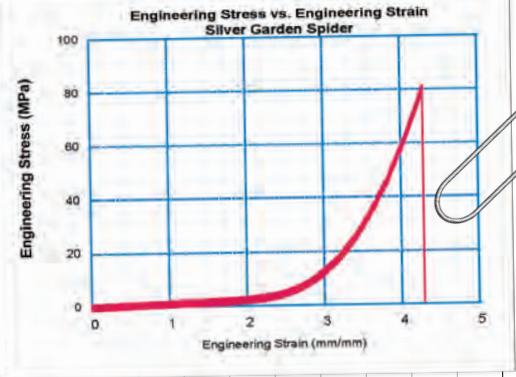
Loading Curve for *Uloborus diversus*

figure 3: (lower left image)

Forcible Silking of *Argiope argentata* (Silver Garden Spider)

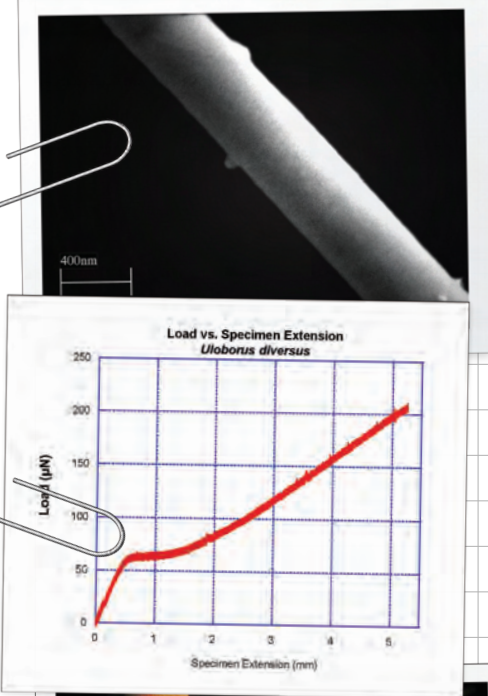
figure 4: (right image)

Loading curve for *Argiope argentata*



**SAMPLE PREPARATION**

Among the greatest challenges of measuring such small fibers are harvesting the specimens and determining a suitable method for mounting them. The samples may be harvested in a variety of ways. Silks are collected from native sources such as webs, egg sacs, draglines, and the swathing silks used to wrap prey. As shown in **figure 3**, silks are also harvested through "forcible silking," a process



RELATED PRODUCT



that entails pulling fibers directly from the spinnerets of anaesthetized spiders.

For spider silks and samples of similar size, a template technique was used for sample preparation. A circular or rectangular window is cut into the template and the specimen is glued across this window. The template is then clamped at both ends in the instrument and cut on either end of the window so the material can be tested.

**DISPLACEMENT SENSING**

A number of spider silk samples were tested using the NANO Bionix system. The three spider silks presented in this Application Note are for the species *Uloborus diversus*, *Argiope argentata* (Silver Garden Spider), and *Latrodectus hesperus* (Western Black Widow). Figure 1 and figure 2 show an SEM image and quasi-static results for *Uloborus diversus*. This sample is of particular interest, as it is only 500 nm in diameter. These fibers can only be seen with the naked eye by the reflection of strong light. Note that the load portion of the curve in figure 2 is in microneutons. *Uloborus diversus* has some notable material characteristics includ-

ing an ultimate tensile strength of 1.150 GPa and a modulus as high as 13.861 GPa. Furthermore, a sample with a stiffness as low as that shown in figure 2 (~ 0.124 N/m) presents significant challenges and exemplifies the capabilities of the NANO Bionix system.

In figure 4, the Engineering Stress/Strain curve can be seen for silk harvested from the species *Argiope argentata*. This silk is often referred to as a "sticky silk" which is not as dry as the other two silks mentioned above. An interesting characteristic of this silk that differs from the other two is the extreme strain that it can withstand. The stress/strain curve is very shallow out to nearly 300% strain before it starts to rise. It is pulled to nearly 430% strain before it breaks.

This remarkable behavior is what allows this material to perform its function so well. Other material properties of interest include the dynamic characteristics (storage and loss modulus) and how these properties evolve as the static strain in the sample is increased. This is done by continuously superimposing an oscillatory force on the loading of the specimen. From this oscillating force and the

resulting displacement oscillation, meaningful dynamic data can be obtained. The ability to make such measurements as the static strain

progresses to very large values is a unique capability of NANO Bionix. Figure 5 and figure 6 show the storage modulus, loss modulus and tangent delta respectively for the spider species *Latrodectus hesperus*. Tangent Delta is the ratio of loss modulus to storage modulus. The dynamic data is impressively quiet for a viscoelastic spider silk with a diameter of 5.574 microns. The capability of the NANO Bionix system to enable accurate measurement of such properties offers valuable support for emerging research on spider silks.

**CONCLUSION**

The NANO Bionix offers unparalleled capability in nano-scale biological material characterization.

This includes the ability to obtain meaningful quasi-static results over large strain ranges along with associated dynamic characteristics of interest. All of this is done with remarkably low noise levels and outstanding resolution.

**ACKNOWLEDGEMENTS**

MTS NANO would like to thank Todd Blackledge and Cheryl Hayashi of the University of California, Riverside for their insight.

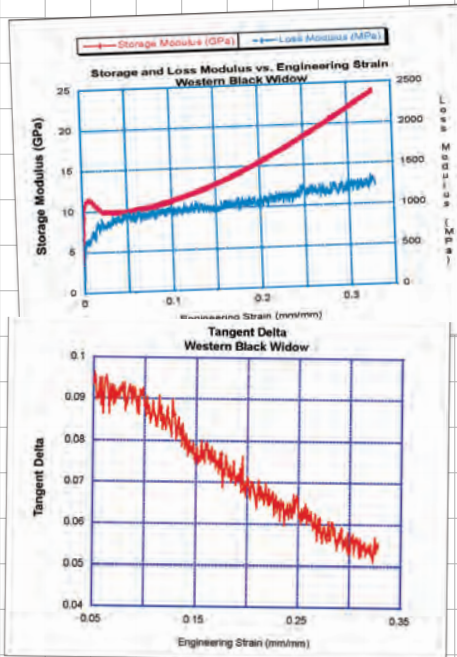


figure 5: Storage and Loss Modulus for *Latrodectus hesperus* (Western Black Widow)

figure 6: Tangent Delta for *Latrodectus hesperus*



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